I. The Action of Potassium Permanganate upon 1-Phenyl-3-Thiourazole and 1-Phenyl-Thiomethylurazole.

II. The Tautomerism of 1-Phenyl-5-Oxy-4,5 Dihydro-3-Triazolyl Methyl Sulphone.

III. The Tautomerism of the Amides.

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

HERBERT AUGUSTUS LUBS

BALTIMORE

1914

MADISON, WIS.
STATE JOURNAL PRINTING CO.
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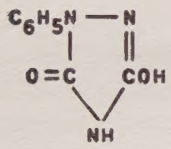
This work was undertaken at the suggestion of Associate Professor Acree and carried out under his supervision, and the author especially wishes to thank him for his constant encouragement and inspiration throughout the work.

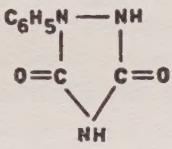
I. The Action of Potassium Permanganate upon 1-Phenyl-3-Thiourazole and 1-Phenyl-3-Thiomethylurazole.

Introduction

1–Phenylurazole can have any of the five following formulas:



I



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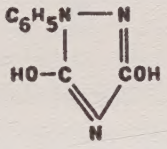

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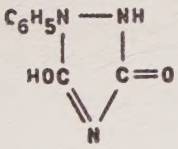
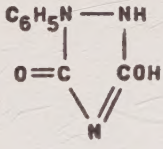


IV



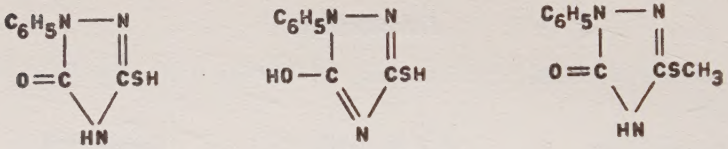
V

The experimental evidence obtained has indicated that in solution, 1–phenylurazole, and any of its salts, consists of an equilibrium mixture of I and II, with a very small amount of III and IV, and practically none of the compound having the formula V.[1]

We might expect that 1–phenyl–3–thiourazole exists appreciably in five similar forms, but the evidence has shown that this is not the case. While the alkylation of 1–phenylurazole under various conditions gives a mixture of nitrogen and oxygen monomethyl esters with various alkylating agents such

[1] Am. Chem. J., **27**, 118; **31**, 185; **32**, 605; **37**, 71, 361; **38**, 1. Ber. d. Chem. Ges., **35**, 553; **36**, 3139; **37**, 184, 618.

as methyl iodide, dimethyl sulphate, and diazomethane, we get only one monoalkyl ester from 1–phenyl–3–thiourazole. When a dialkyl ester is made, we get a mixture of two isomeric nitrogen and oxygen esters. From this alkylation evidence, and from the evidence obtained by Shadinger[2] on the affinity constants of the urazoles, it appears that 1–phenyl–3–thiourazole exists in solution almost entirely in the two following forms:



VI

The monomethyl ester was given the formula VI:

for the following reasons:[3] this substance is the only monoalkylation product isolated when 1–phenyl–3–thiourazole is treated with diazomethane, methyl iodide, dimethyl sulphate, or methyl alcoholic hydrochloric acid, or when the sodium salt of 1–phenyl–3–thiourazole is acted upon by methyl iodide or dimethyl sulphate. When this ester is heated with acids under pressure methyl mercaptan is split off, and upon oxidation it behaves like a thioether. The oxidation evidence will be further discussed later. The production of a mercaptan cannot be taken as conclusive evidence, as only a small amount was produced, and this could have been due to a small amount of impurity present. From Shadinger's work on the affinity constants of 1–phenyl–3–thiourazole it is very probable that in the sodium or potassium salts, the sodium or potassium is joined to the sulphur, and it seemed likely that the methyl is also attached to the sulphur. As all of this evidence, however, has not been substantiated by a wide study of the reactions of these alkyl thiourazoles nor by direct syntheses, leaving no room for doubt, it was thought wise to begin some investigations of the reactions of these alkyl thiourazoles that will shed a clearer light

[2] Am. Chem. J., 39, 124.
[3] Esslinger, Diss. J. H. U., 1912, p. 2.

on the question whether the alkyl is joined to the sulphur at 3 or the nitrogen at 2. We, therefore, began a study of the oxidation of the methyl ester formed by alkylating 1–phenyl–3–thiourazole with the hope of securing derivatives that leave no doubt concerning the position of the methyl group.

Work by Marshall[4] on the sodium salt of 1–phenyl–2–methylurazole has shown that the equilibrium ratio of the two tautomeric forms of the urazole salt is different from that of the two tautomeric forms of the free 1–phenyl–2–methylurazole. Marshall, working at —70° with diazomethane as the alkylating agent, found that two different ratios of esters were obtained from 1–phenyl–2–methylurazole, the results depending upon whether the acid itself was alkylated or the acid is liberated from the sodium salt and immediately alkylated. Even in fifteen seconds the liberated acid underwent a tautomeric or other change and gave a ratio of esters which corresponded to that obtained from the free urazole acid itself. His results show the rapidity with which equilibrium is established between the two forms.

Previous work[5] has also shown that the nature of the solvent had an appreciable effect upon the ratios of esters obtained by alkylating various urazoles and thiourazoles. The evidence obtained up to the present time has not enabled us to decide whether this effect is due to a change in the equilibrium point between the tautomeric forms, or to a change in the velocity constants of the reactions of the two forms or to other factors.

Except in *one case,*[6] the experimental evidence has been such as to indicate that temperature had no appreciable effect upon the ratio of esters obtained by alkylating various urazoles under various conditions. It is almost universally true, that for a given salt and alkyl halide, the ratio of esters obtained is independent of variation in temperature. The one exception to this was the allyl ester obtained by treating the silver salt of 1–phenyl–4–methylurazole with allyl iodide. This was the

[4] Marshall, Diss. J. H. U., 1911, p. 34.
[5] Acree and coworkers, Ber. d. Chem. Ges., **41,** 3230. Nirdlinger, Diss. J. H. U., 1909.
[6] Ber. d. Chem. Ges., **41,** 3230.

only case in which it was found that at the higher temperature a larger percentage of N–ester was formed; and furthermore the per cent N–ester formed, within certain limits, was dependent upon time. The experimental facts in this case are very meager and more work is necessary before the results can be interpreted properly.

Acree and his co-workers have shown that in the alkylation of the thiourazoles, both the urazole anion and the nonionized urazole take part.[7] They have further shown that a constant ratio of esters is apparently obtained with a given urazole and given alkyl halide even with changes in concentration and consequent changes in ionization. It has also been shown that the addition of a neutral salt, which suppresses the ionization of the urazole salt, had no appreciable effect on the ratio of esters obtained.[8] This evidence tends to show that the equilibrium between the tautomeric forms is established between the molecular forms rather than between the anions and that the ions and molecules react with the alkyl halide with approximately evidence is needed along this line, and work to this end is now in progress.

The work on the oxidation of 1–phenyl–3–thiourazole was undertaken principally in order to attempt to oxidize away the sulphur in position 3, and in this way obtain 1–phenyl–3–5–dioxyurazole. In this manner we could establish the connection between these two compounds.

The preliminary work on this problem was done by E. W. Esslinger.[9]

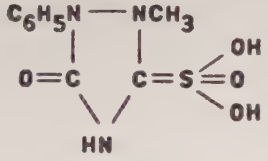
When 1–phenyl–3–thiomethylurazole, in alkaline solution, was treated with a solution of potassium permanganate, instead of obtaining a phenyloxyurazole, it was found that the methylthiourazole was oxidized to a white crystalline compound, 1–phenyl–4–5–dihydro–5–oxy–3–triazolyl methyl sulphone.[10] This compound melted at 206°, while the original urazole melted at 195°. The two substances were very similar in prop-

[7] Nirdlinger and Rogers, Am. Chem. Journ., **49**, 116; Chandler, Diss. J. H. U., 1912.
[8] Acree and coworkers, Ber. d. Chem. Ges., **41**, 3230.
[9] Diss. J. H. U., 1912.
[10] This compound will be designated hereafter by the term methyl sulphone for the sake of brevity.

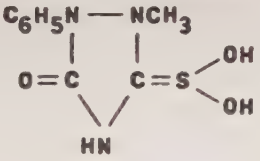
erties. Even when this sulphone is boiled in alkaline solution with an excess of potassium permanganate, it is not further attacked. This oxidation product gives us more evidence for the correctness of the assumption that the monoalkyl derivative formed by alkylating 1–phenyl–3–thiourazole is really 1–phenyl–3–thiomethylurazole, VI.

If the methyl group were not attached to the sulphur in position 3, then of necessity, it must be joined to the nitrogen in position 2, as 1–phenyl–3–thio–4–methylurazole has been synthesized by an independent method which leaves no doubt as to its structure.

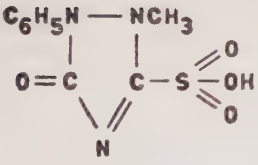
If the methyl is in position 2, when we oxidize the methyl urazole, the following oxidation products would be possible:



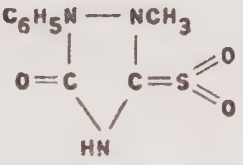
VII



VIII

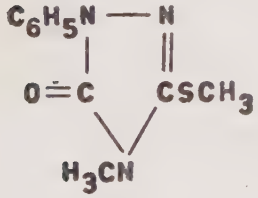


IX

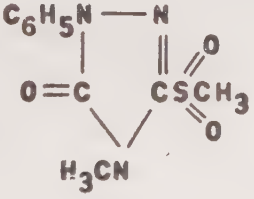


X

If we take the dialkyl compound XI:



XI



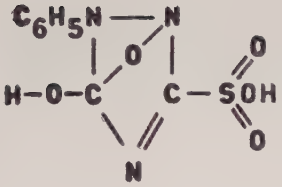
XII

and oxidize it in glacial acetic acid by means of potassium permanganate we obtain the same compound which is formed when the potassium salt of the oxidized monoalkyl thiourazole is heated with methyl iodide, namely, XII.

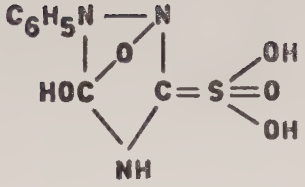
This compound is absolutely neutral and this fact eliminates the possibilities VII, VIII and IX, or similar compounds. The possibility of X being formed is made improbable by the fact that there are no such sulphur compounds known. X is a derivative of sulphur trioxide and would take up water and form an acid. Of course, it must be realized that other compounds are possible, but these four forms are sufficient to illustrate the point. The other possible compounds would be eliminated by the same reasoning.

The above evidence seems to confirm strongly the supposition that the 3–thioalkyl compound is obtained on alkylating 1–phenyl–3–thiourazole. This chemical evidence taken in conjunction with the physical chemical evidence obtained by Shadinger in his work on the affinity constants of the 1–phenyl–3–thiourazole makes the proof quite conclusive, that the alkyl joins the sulphur when 1–phenyl–3–thiourazole is alkylated. The analysis of the oxidized 1–phenyl–3–thiomethylurazole gave 13.35 per cent sulphur, whereas the theoretical for $C_9H_9N_3SO_3$ is 13.45 per cent.

The results obtained by the oxidation of 1–phenyl–3–thiourazole itself were not so satisfactory. Upon treatment of the urazole, in hot alkaline solution, with an excess of potassium permanganate, a compound was obtained whose composition seemed to correspond to the formula $C_8H_7N_3SO_5$ or $C_8H_9N_3SO_5$, that is, perhaps XIII and XIV. The formula $C_8H_9N_3SO_5$ corresponds to hydrated $C_8H_7N_3SO_4$, or 1–phenyl–4, 5–dihydro–5–oxy–3–triazolyl sulphonic acid, and seems to be the correct one, for the acid obtained actually loses a molecule of water at 135°. Esslinger obtained the corresponding 1–phenyl–4, 5–dihydro–5–oxy–3–triazolyl sulphinic acid.



XIII



XIV

This compound when recrystallized from acetic acid melted at 263–4° and was quite different in properties from the 1–phenyl–3–thiourazole. When alkylated with diazomethane it gave products which were soluble in water, and which in no way resembled the oxidized dialkyl ester of 1–phenyl–3–thiourazole.

Attempts were made to obtain an intermediate compound by the addition of potassium permanganate just sufficient to furnish two atoms of oxygen. Apparently a compound was obtained differing from that formed when an excess of potassium permanganate was used, but it was evidently a mixture of several different substances with solubilities so similar that they could not be separated by means of ordinary solvents.

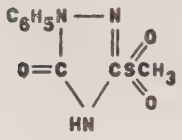
The compound melting at 263–4°, when fused with phosphorus pentachloride, gave an acid chloride, which is quite stable in cold water and is decomposed only when boiled for some minutes. When heated with alcohol, an ester is formed. Alkali decomposes the chloride immediately. Further work will be done to obtain evidence on the constitution of this substance and to prepare the intermediate compounds.

Upon investigating the properties of 1–phenyl–5–oxy–4–5–dihydro–3–triazolyl methyl sulphone, XV, it was found that this compound was extremely well adapted to the study of tautomerism. This substance can be obtained easily in pure condition and is very stable. Its esters are stable white crystalline substances and are non-volatile at the temperatures to which it is necessary to subject them.

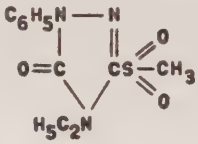
An interesting fact in connection with the esters derived from this substance is that when we alkylate the sodium salt

with ethyl iodide, about 90 per cent of the nitrogen ester is formed, and when the silver salt is alkylated we get practically 97 per cent of the oxygen ester. These facts rendered possible the ready isolation of the nitrogen and oxygen esters in a practically pure condition.

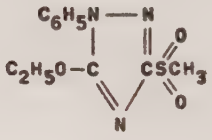
The form XVI melts at 116°, while the form XVII melts at 97°.



XV



XVI



XVII

It is interesting to note that a change in position of the ethyl group from the nitrogen to the oxygen makes a difference of 19° in the melting point, nearly all other such pairs having the melting points closer together. These esters are perfectly stable and do not seem to rearrange into one another; or if they do, the amount of change is so small that it cannot be detected.

In order to obtain information about the tautomeric properties of the methyl sulphone, the free sulphone and also its salts were alkylated under various conditions with very interesting results. It was found that the ratios of esters obtained bore a fairly close relation to the ratio of esters obtained by alkylating 1–phenyl–3–thiomethylurazole under the same conditions. By alkylating the sodium salt of 1–phenyl–3–thiomethylurazole in 40 per cent alcohol with ethyl iodide, Johnson obtained 88.4 per cent N–ester. Alkylation of the sodium salt of the methyl sulphone under the same conditions gave 90 per cent of N–ester. In both cases it was found that alkylation of the silver salt gave more than 80 per cent of O–ester.

In conclusion it seems that the evidence as a whole shows that the 1–phenyl–3–thiourazole is a true 3–thiol and that the mono alkylation product is a 3–thio methyl ester.

Various theories have been proposed to account for the phenomenon of tautomerism. Among these are the theories of

Comstock,[11] Wheeler,[12] Nef,[13] and Michael.[14] One of the facts which these theories try to explain is how two or more stable isomeric products can be obtained by the action of a reagent upon a tautomeric substance. Though these theories have been shown to fit in with the facts in *certain* cases, yet an enormous amount of experimental evidence obtained in this laboratory has shown that these theories are not of general applicability.

According to Acree's theory of tautomerism, in the cases in which the urazoles, their salts and derivatives give two or more stable products as a result of the reaction, they do so because they exist (A) in one tautomeric form alone which yields two or more derivatives through independent side reactions,[15] or (B) in two or more forms in equilibrium, each of which gives its own derivatives through an independent reaction. The work of Marshall previously mentioned makes the later possibility more probable. As yet, this theory can be accepted only tentatively, as more experimental evidence is needed to render it conclusive. However, the present facts fit in well with the theory and the theory furnishes a good working hypothesis.

Acree[16] has shown mathematically and experimentally that the factors which influence the ratio of stable alkyl or other derivatives from a tautomeric compound are principally: (1) The relative reactivity of the two tautomeric forms toward the reagent; (2) the ratio between the amounts of two or more tautomeric forms when they are in constant equilibrium with each other; and (3) the rapidity of the change of each of these tautomeric forms into the other as the equilibrium is disturbed. Consideration of these possibilities makes evident the complexity of the problem, and the necessity of vastly more experimental evidence.

Briefly considered, the other theories to account for the phenomenon of tautomerism are as follows:

I. Comstock's Theory: The potassium and the silver salts of

[11] Ber. d. Chem. Ges. **23,** 2270; Am. Chem. J., **12,** 493; **13,** 514, 525.
[12] Am. Chem. J., **21,** 187; **23,** 135; **30,** 28.
[13] Ann. Chem. (Liebig), **261,** 52; **276,** 200; **277,** 59, 83.
[14] J. Prakt. Chem., **37,** 469; **45,** 580; **46,** 189; Am. Chem. J., **43,** 322.
[15] For mathematical discussion of this theory, see Acree, Am. Chem. J., **38,** 1.
[16] Ibid., **38,** 8.

tautomeric amides have different but definite structures. The potassium salt is a nitrogen compound and the silver salt is an oxygen compound. The fact that the sodium and silver salts of the methyl sulphone give both oxygen and nitrogen esters and that the ratio of these esters varies with the salt and the alkyl halide indicates that the application of this theory is not general.

II. Wheeler's Theory: When the salt of a tautomeric acid and a certain reagent yield two isomeric products, one is formed directly from the salt and the second product is formed by a rearrangement of the first. From his experimental results Wheeler assumed that all salts of amides are oxygen derivatives and that these first yield oxygen esters, which then form addition products with the alkyl halide and rearrange catalytically into nitrogen esters.

In the present work and in the previous work on the urazole esters, with the one possible exception of an O–allyl ester, no cases have been found in which either the O–ester or the N–ester rearranged under the conditions of the experiment. Further, the ratio of O–ester to N–ester does not change with time and temperature, as would certainly be the case if Wheeler's theory held in general. If the O–ethyl ester derived from methyl sulphone rearranged, it would be difficult to see how 97 per cent of O–ester would be obtained from the silver salt, both at room temperature and after heating the reaction mixture, containing a large excess of alkyl halide, at 100° for six hours. Furthermore, about 90 per cent of N–ester is obtained from the sodium salt.

III. The Theories of Michael and Nef: When the salt of a tautomeric compound, and another reagent yield two isomeric products, one is formed by direct substitution of the metal and the other by the decomposition of an unstable intermediate addition product formed by the union of the salt and the other reagent. Acree[17] and co-workers have obtained a great abundance of experimental evidence showing that this theory is not applicable to the case of various urazole esters.

[17] Ber. d. Deut. Chem. Ges., **41**, 3207.

EXPERIMENTAL

1–Phenyl–3–thiosemicarbazide[18]

$C_6H_5NH\ NH\ CS\ NH_2$

This compound was prepared by heating together phenylhydrazine hydrochloride and ammonium sulphocyanate in absolute alcohol. A large excess of the sulphocyanate was used. The 1–phenyl–3–thiosemicarbazide separated out as a white crystalline mass, which was filtered off and then ground up with warm water in a large dish in order to remove the ammonium chloride formed in the reaction and also the unchanged ammonium sulphocyanate. The semicarbazide can then be further purified by recrystallization from alcohol. The melting point of the recrystallized compound is 204° C.

1–Carbethoxy–1–phenyl–3–thiosemicarbazide[19]

$$C_6H_5N\text{–}NH\text{–}CS\ NH_2$$
$$|$$
$$COOC_2H_5$$

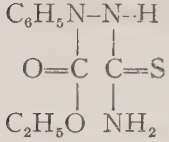
This compound was readily prepared by the action of ethylchlorcarbonate ($ClCOOC_2H_5$) on 1–phenyl–3–thiosemicarbazide in an acetone solution. When the finely powdered 1–phenyl–3–thiosemicarbazide was suspended in acetone, and boiled up with ethylchlorcarbonate, it gradually went into solution and 1–carbethoxy–1–phenyl–3–thiosemicarbazide precipitated out. It was filtered off, washed with cold acetone and recrystallized from alcohol. Pure 1–carbethoxy–1–phenyl–3–thiosemicarbazide melts at 232°, with decomposition.

1–Phenyl–3–thiourazole[20]

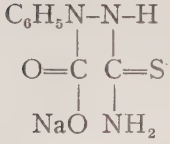
This compound was made by saponifying 1–carbethoxy–1–phenyl–3–thiosemicarbazide with one molecular equivalent of sodium hydroxide in the presence of the indicator phenolphthalein. When this sodium salt is treated with an excess of sulphuric acid, the corresponding acid is formed; but this acid is

[18] Ber. d. Chem. Ges., **26**, 2812.
[19] Ibid., **36**, 3151.
[20] Ber. d. Chem. Ges., **36**, 3141.

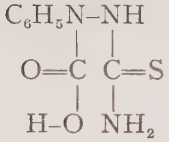
unstable under the existing conditions, immediately loses water and gives 1–phenyl–3–thiourazole.



1–Phenyl–1–carbethoxy–3–thiosemicarbazide + NaOH



Sodium salt of 1–Phenyl–3–thiosemicarbazide–carboxylic acid + H_2SO_4



1–Phenyl–3–thiosemicarbazide – 1 – carboxylic acid

This acid loses one molecule of water as indicated above and forms the corresponding 1–phenyl–3–thiourazole.

When pure, 1–phenyl–3–thiourazole is a white, crystalline compound, which melts at 195°. As ordinarily prepared it has a slightly yellowish tinge, due perhaps to a small amount of disulphide present. It can be recrystallized from alcohol.

1–Phenyl–3–thiourazole titrates almost quantitatively as a monobasic acid when phenolphthalein is used as the indicator. Though there is another replaceable hydrogen atom in the 4–5 amide group, yet its presence is not shown by any indicator. When the hydrogen of the –SH group is replaced by an alkyl group, then the hydrogen in the 4–5 amide group becomes sufficiently acidic in solution to be titrated quantitatively. The reason for this is explained by Esslinger in his dissertation.

Action of Potassium Permanganate on 1–Phenyl–3–thiourazole

The 1–phenyl–3–thiourazole was dissolved in boiling water containing a slight excess of sodium hydroxide. To this hot solution was added a hot solution of potassium permanganate containing somewhat more than two atomic equivalents of oxy-

gen. The excess of permanganate was reduced by adding alcohol to the solution and boiling it for a few minutes. The manganese dioxide was then filtered off and the solution was made neutral with nitric acid. Addition of silver nitrate gave a white precipitate. The silver salt, when filtered and washed, was suspended in water in a flask, and treated with hydrogen sulphide with frequent agitation. The silver sulphide was filtered off and the filtrate was evaporated to dryness on the water bath. When recrystallized from glacial acetic acid the product obtained melted at 263°–264°. It is insoluble in chloroform, ether and benzene, but is soluble in alcohol, water, acetic acid and acetone.

Action of 30 Per Cent Hydrogen Peroxide on 1–Phenyl–3–thiourazole

When 1–phenyl–3–thiourazole was dissolved in a hot saturated solution of sodium carbonate and treated in a beaker with an excess of 30 per cent hydrogen peroxide, a violent action ensued. The solution was neutralized with nitric acid and the oxidized urazole precipitated in the usual way as the silver salt. When this silver salt was treated with hydrogen sulphide, a substance was obtained which was identical with the acid formed by treating 1–phenyl–3–thiourazole with an excess of permanganate. When oxidizing phenyl–thiourazole with hydrogen peroxide an excess of alkali must be used or the urazole will be oxidized merely to the disulphide.

In an attempt to isolate an intermediate oxidation product, an alkaline solution of 1–phenyl–3–thiourazole was treated with sufficient permanganate to yield one atomic equivalent of oxygen. The products obtained could not be separated and identified. They were apparently rather unstable, and gave off sulphur dioxide when heated in aqueous acid solution.

When a cold alkaline solution of 1–phenyl–3–thiourazole was treated with sufficient permanganate to furnish two atomic equivalents of oxygen, a product was obtained which, upon acidulation of the aqueous solution, evolved sulphur dioxide;

simultaneously a substance insoluble in water precipitated out. Other soluble products were formed, which, though stable, were impure and could not be separated.

When 1–phenyl–3–thiourazole was oxidized by hydrogen peroxide in acetic acid solution only the disulphide was obtained.

Analysis:

I. 0.3448 grms. of the compound melting at 263°–264° gave by Carius' method, 0.3144 grms. Ba SO_4.

II. 0.3022 grms. by sodium peroxide method gave 0.2758 grms. Ba SO_4.

III. 0.3537 grms. by sodium peroxide method gave 0.3258 grms. Ba SO_4.

Sulphur found:

I. 12.53%. II. 12.53%. III. 12.65.%

Theoretical for, $C_8N_3SO_4H_7$, 13.28% S.

Theoretical for, $C_8N_3SO_5H_7$, 12.45% S.

Theoretical for, $C_8N_3SO_5H_9$, 12.35% S.

The percentage of sulphur found is rather low for the first theoretical formula given; however, there is a possibility that the compound formed has more oxygen in the molecule than is given in the formula above. One more atom of oxygen in the molecule would make the analytical result accord much more closely with the theoretical formula, as would also a molecule of water.

The oxidized urazole behaves almost as a dibasic acid having the formula $C_8N_3SO_5H_7$ or $C_8N_3SO_5H_9$, as the following titrations of different samples show:

Titrations of the 263°–4° M. Pt. Acid Against Standard Alkalies

Weight of acid in grams.....	0.2632	0.0712	0.2084	0.2194	0.2103
Cc. alkali required	20.05 cc 0.0987 N NaOH	5.40 cc 0.0987 N NaOH	15.47 cc 0.0987 N NaOH	16.72 cc 0.0987 N NaOH	15.99 cc 0.0994 N NaOH
Cc. alkali calculated for $C_8N_3SO_4H_7$	22.01 cc	5.95 cc	17.50 cc	18.42 cc	17.54 cc
Cc. alkali calulated for $C_8N_3SO_5H_7$	20.72 cc	5.62 cc	16.41 cc	17.28 cc	16.44 cc
Cc. alkali calulated for $C_8N_3SO_5H_9$	20.56 cc	5.56 cc	16.28 cc	17.04 cc	16.33 cc

Silver Salt of Oxidized 1–Phenyl–3–thiourazole

The oxidized urazole, m. p. 263–4, was dissolved in water and neutralized with sodium hydroxyd in the presence of phenolphthalein. To the solution was then added an excess of silver nitrate. A white precipitate was obtained which darkened rapidly in alkaline solution, but which remained perfectly white in a slightly acid solution. The precipitate was filtered off and thoroughly washed with water, alcohol, and ether. From the analysis this salt is apparently a disilver salt. The monosilver salt could not be made.

This silver salt can be recrystallized, if necessary, by dissolving it in boiling two per cent nitric acid. The silver salt crystallizes out upon cooling the solution.

Analysis of silver salt:

I. 0.3489 grms. silver salt gave 0.1593 grms. silver.

II. 0.4805 grms. silver salt gave 0.2190 grms. silver.

Silver found:

I. 45.61%. II. 45.58%.

Theoretical for $C_8H_5N_3SO_4Ag_2$, 47.42% Ag.

Theoretical for $C_8H_5N_3SO_5Ag_2$, 45.81% Ag.

Theoretical for $C_8H_7N_3SO_5Ag_2$, 45.61% Ag.

The sulphur content of the acid melting at 263°–4°, the titrations against standard sodium hydroxide, and the analysis of the di-silver salt all harmonize more closely with the formula $C_8N_3SO_5H_7$ or $C_8N_3SO_5H_9$ than with the formula $C_8N_3SO_4H_7$ for the 1–phenyl–4, 5 dihydro–5–oxy–3 triazolyl sulphonic acid. The constitutional formula of this acid will now be discussed further.

Composition and Constitution of the 263–4° m. pt. Acid

Formulae XIII and XIV correspond to 1–phenyl–4, 5–dihydro–5–oxy–3–triazolyl sulphonic acid plus 1 atom of oxygen or 1 molecule of water of crystallization or constitution. Mr. E. H. Wight has found that no appreciable loss in weight occurs when the acid is heated at 105° but that at 135° 1 mole-

cule of water is lost in conformity with formula XIV. The melting point is not changed.

0.5553 grams 263° melting point acid lost 0.0396 grams water in 10 hours at 135°. Calculated for $C_8N_3SO_4H_7 \cdot H_2O$, 6.96 per cent; found 7.1 per cent. Upon standing 0.3979 grams of the dry material took up 0.0281 grams, or 7.06 per cent, water from the atmosphere.

0.3294 grams 263° melting point acid lost 0.0246 grams water in 10 hours at 135°. Loss 7.5 per cent; calculated 6.96 per cent. Upon standing 0.3034 grams of the dry material took up 0.0246 grams, or 8.1 per cent, water from the atmosphere.

The remaining anhydrous acid, $C_8H_7N_3SO_4$, should normally have a sulphonic acid group at 3 and it became interesting to see (1) whether this substance recombines immediately with water in aqueous solutions and gives the original hydrated dibasic acid, or (2) whether the acid fails to hydrate immediately and only the sulphonic acid titrates against alkalies in the presence of phenolphthalein, and the 4,5 amid groups then fails to do so, as in the case of the monobasic salts of phenyl urazole and phenyl–3–thiourazole, or (3) whether both the sulphonic acid group and the 4,5 amid group can be titrated. Accordingly some of the anhydrous acid was titrated with alkalies immediately after solution and was found to be *dibasic*.

0.0881 gram anhydrous acid, melting point 263°, required 7.46 cc 0.0938 N potassium hydroxide; calculated for a dibasic acid, 7.78 cc.

It was thought that the strong sulphonic acid group might catalytically accelerate the addition of water, and that the acid might titrate as a monobasic acid if it were quickly dissolved in an *excess* of alkali at 0° and the solution were immediately neutralized with a standard acid. This would especially be the case if the water added slowly as water of constitution, as illustrated in XIV. Even under these conditions, however, the acid behaved as a dibasic acid.

0.0576 gram anhydrous acid, melting point 263°, dissolved in 7.73 cc 0.0938 N potassium hydroxide at 0°, required 2.88 cc 0.0938 N hydrochloric acid for neutralization in the presence

of phenolphthalein. Alkali required, 4.85 cc; calculated for a dibasic acid, 5.10 cc.

It is clear then that two very important problems are open for investigation. (1) If the water does not add immediately or adds simply as water of crystallization to the triazolyl–3–sulphonic acid, both the sulphonic acid group and the 4,5 amid group evidently titrate against alkalies. The readiness with which the anhydrous acid absorbs water from the atmosphere makes it possible that the acid becomes hydrated immediately upon solution. In this case the molecular conductivity in N/1000 solution will be practically that of a phenol sulphonic acid, somewhere around 375, as White found for phenolsulphonphthalein. (2) If the water adds as water of constitution, as in XIV, and gives a sulphuric acid derivative, the titration as a dibasic acid is self evident. If the water lost by the free acid at 135° is not water of crystallization but of constitution, as in XIV, and if one of the OH groups attached to the S of the free acid, XIV, is involved in this loss of water, it is clear that *the salts* might not lose the molecule of water. It is, therefore, highly significant that the disilver salt of this hydrated acid does not lose water even at 150°–160°, and it looks as if the water is that of constitution. In N/1000 solutions such a dibasic acid as XIV should, therefore, have a molecular conductivity *much higher* than 375, perhaps around 600 to 700. These conductivity experiments will be carried out by Mr. E. H. Wight, and should throw great light on this constitutional problem. The oxidation of 1–phenyl–3–thiol–4–methyl urazole to the corresponding 1–phenyl–4–methyl–3–triazolyl sulphonic acid, which is already in progress, will be very interesting in this connection from both the conductivity and constitutional points of view.

We are furthermore devising some experiments with the oscillagraph, which has a period of 1/3000 second, in order to measure rapid chemical changes such as neutralization, hydration, tautomeric phenomena, and others of a similar nature. The possible combination of the anhydrous acid with alcohol will make all these studies in this solvent important.

1–Phenyl–3–thiomethylurazole, VI [21]

1–Phenyl–3–thiourazole was dissolved in alcohol, neutralized with sodium hydroxide in the presence of phenolphthalein, and then treated with 1.5 molecular equivalents of methyl iodide (CH_3I). This solution was heated to boiling under a reflux condenser and then cooled, whereupon the 1–phenyl–3–thiomethylurazole precipitated out. This was filtered off and the filtrate was evaporated to dryness to recover the soluble portions. The 1–phenyl–3–thiomethylurazole was extracted from the small amount of neutral dimethyl ester by alkali and reprecipitated with dilute hydrochloric acid. When recrystallized from alcohol a 90 per cent yield of the white substance was obtained which melted at 173°, undecomposed. This ester titrates nearly quantitatively against one molecule of alkali in the presence of phenolphthalein.

Oxidation of 1–Phenyl–3–thiomethylurazole with Potassium Permanganate

The 1–phenyl–3–thiomethylurazole was suspended in water and dissolved by heating with an equivalent of sodium hydroxide. A slight excess of alkali was then added and the solution treated with an excess of potassium permanganate in hot aqueous solution. The excess of permanganate was reduced by adding alcohol to the hot solution. The manganese dioxide was then filtered off and the solution was acidulated. The methyl sulphone precipitated as a white pasty mass. The sulphone was purified by dissolving it in alkali reprecipitating it with acid, and recrystallizing it from alcohol. The sulphone is a white crystalline compound, which melts at 206°, and titrates almost quantitatively as a monobasic acid, when phenolphthalein is used as the indicator.

The yield of the sulphone from the oxidation of 1–phenyl–3–thiomethylurazole is practically quantitative.

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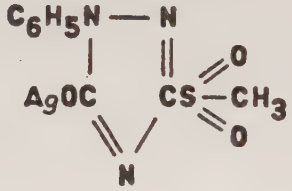
[21] Ber. d. Chem. Ges., 36, 3152.

Analysis:

I. 0.3435 grms. methyl sulphone gave 0.3318 grms. Ba SO_4. Found, 13.27% S. Calculated for $C_9H_9N_3SO_3$, 13.45%

II. 0.4903 grms. methyl sulphone gave 0.4788 grms. Ba SO_4. Found, 13.42% S. Calculated for $C_9H_9N_3SO_3$, 13.45%.

Silver Salt 1–Phenyl–5–oxy–4–5–dihydro–3–triazolyl methyl sulphone



XVIII

This salt was made by dissolving the sulphone in alcohol and neutralizing it with alkali in the presence of phenolphthalein. An excess of silver nitrate was then added, and the silver salt precipitated as a stable, white powder. This was filtered off and washed with water, then with alcohol and ether.

Analysis:

Before analysis was made the silver salt was dried at 120°–130° for several hours.

I. 0.2565 grms. silver salt gave 0.080 grms. silver.

II. 0.4084 grms. silver salt gave 0.1270 grms. silver.

III. 0.3167 grms. silver salt gave 0.0986 grms. silver.

Silver found:

I. 31.06%. II. 31.09%. III. 31.18%.

Theoretical for, $C_9H_8N_3SO_3Ag$, 31.18% silver.

1–Phenyl–5–oxy–4,5–dihydro–4–methyl–3–triazolyl methyl sulphone, XII, formed by the oxidation of 1–Phenyl–3–thiomethyl–4–methylurazole, XI

The 1–phenyl–3–thiomethyl–4–methylurazole compound was prepared in the usual way by treating 1–phenyl–3–thiourazole

with two molecular equivalents of alkali, adding about two and one-half equivalents of methyl iodide, and heating the solution one hour. The resulting dimethyl ester was purified by dissolving it in chloroform and extracting this solution with alkali to remove the unchanged urazole and the 1–phenyl–3–thiomethylurazole. The choloroform extract was then evaporated off, and the residue heated with alcoholic hydrochloric acid to hydrolyze the O–ester formed in the reaction. The reaction product was dissolved in chloroform and extracted with alkali to remove the 1–phenyl–3–thiomethylurazole formed by the hydrolysis of the 5–O–ester. The chloroform was evaporated and the residue recrystallized from alcohol.

The dimethyl urazole was dissolved in hot glacial acetic acid, treated with an excess of finely powdered potassium permanganate and then boiled for a few minutes. The acetic acid was diluted with water and the whole mass poured into a separatory funnel. This solution as then extracted with chloroform, which was filtered, washed with water, and then evaporated. When the residue was recrystallized several times from alcohol it melted at 105°–106°. This compound was found to be identical with the N–ester obtained by methylating the methyl sulphone in the manner to be described later.

The same compound was obtained by oxidizing the dimethyl thiourazole ester in a benzene solution with potassium permanganate in the presence of sulphuric acid.

REDUCTION EXPERIMENTS

When the methyl sulphone was dissolved in alcohol, treatment with zinc dust and hydrochloric acid effected no appreciable reduction.

When dissolved in acetic acid and treated with zinc dust, the methyl sulphone was not reduced.

Oxidized 1–phenyl–3–thiourazole was not reduced by either of the above methods.

II. The Tautomerism of 1-Phenyl-5-Oxy-4,5 Dihydro-3-Triazolyl Methyl Sulphone.

Ratio of esters obtained from the soduim salt of methyl sulphone when alkylated with methyl iodide and ethyl iodide.

Preparation of the Solution: The sulphone was dissolved in alcohol, and neutralized with aqueous alkali. To this solution an excess of the alkyl halide was added. In some of the first experiments the reaction mixture was heated upon a water bath in a small flask attached to a return condenser. Later it was found more satisfactory to allow the mixture to react in a sealed tube in a water bath at 100°.

Separation of Esters Formed: The method used to extract the ester was that suggested by Acree and used by Johnson, Nirdlinger, Marshall and Brunel. After heating the reaction mixture the necessary length of time, the volume of the solution was reduced by careful distillation, if necessary, to 5 or 10 c. c.; then it was transferred directly to a small separatory funnel, which contained about 50 c. c. of water. Sufficient dilute alkali was added to the aqueous layer to cause the pink color of phenolphthalein to persist after agitating the reaction mixture. This solution was extracted five times with redistilled chloroform and after each extraction the chloroform was transferred to a similar separatory funnel containing about 50 c. c. of water made slightly alkaline. The chloroform solution of the esters was run into a small weighed porcelain dish after each extraction. The chloroform was evaporated off by placing the dish upon a water bath and blowing gently over the surface of the chloroform. This enables us to evaporate off the solvent below its boiling point, and further, prevents the creeping of the ester over the edge of the dish. The ester is then placed in a vacuum dessicator containing sulphuric

acid, and allowed to come to constant weight. In this way, we get the weight of the total amount of ester formed.

Hydrolysis of the 5–O–Ester: When the mixture of esters has come to constant weight it is transferred by means of chloroform to a glass tube drawn out and sealed at the bottom, and constricted at the top. The constriction at the top facilitates the sealing of the tube. The chloroform is then evaporated off and 3 c. c. of absolute alcohol saturated with hydrochloric acid gas is added. The tube is then sealed and heated at 100° for one hour. The hydrochloric acid decomposes the O–ester into methyl chloride and the methyl sulphone, which is soluble in alkali, whereas the N–ester is unattacked. By extracting the solution as described above, the alkali salt formed is dissolved in the aqueous layer and the neutral ester is extracted by means of chloroform. The chloroform extract is then run into a weighed dish and evaporated in the usual way. Knowing the weight of N–ester formed, by difference we know the weight of the O–ester.

Alkylation of the Sodium Salt

Sodium Salt of of 1–Phenyl–5–Oxy–4–5–Dihydro–3–Triazolyl Methyl Sulphone and Methyl Iodide in a Mixture of Alcohol and Water, When Heated Four Hours in a Small Flask on the Water Bath

Wt. Sulphone	c. c. Methyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent N–Ester
About 2 grms.	4	1.2758 grms.	1.2660 grms.	99.2
About 2 grms.	4	1.1604 grms.	1.1157 grms.	96.1
			Average	97.6

Sodium Salt and Methyl Iodide in a Mixture of Alcohol and Water, Heated Four Hours in a Sealed Tube at 100°

Wt. Sulphone	c. c. Methyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent N–Ester
0.7639	4	0.5927 grms.	0.5743 grms.	96.9
0.5750 (sodium salt)	2	0.4335 grms.	0.4112 grms.	94.9
			Average	95.9

Sodium Salt and Ethyl Iodide in a Mixture of Alcohol and Water, Heated Four Hours in a Sealed Tube at 100°

Wt. Sulphone	c. c. Ethyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent N–Ester
0.4963	4	0.1598 grms.	0.1478 grms.	92.5
0.4664	2	0.1418 grms.	0.1281 grms.	90.3
0.5167 (sodium salt)	2	0.2083 grms.	0.1843 grms.	88.5
			Average	90.4

Alkylation of the Silver Salt

In alkylating the insoluble silver salt, it was suspended in ether, the alkyl halide added, and the tube sealed. In the beginning of the work these alkylations were carried on at room temperature in small flasks closed with corks. Both tubes and flasks were shaken at frequent intervals.

Silver Salt of Methyl Sulphone and Methyl Iodide in Ether, in a Small Flask at Room Temperature for Three Days

Wt. Silver Salt	c. c. Methyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent O–Ester
0.5 grms.*	9	0.3533 grms.	0.0533 grms.	85.0

*This was one of the first ratios determined and the high ratio may possibly be due to experimental error.

Silver Salt of Methyl Sulphone and Methyl Iodide in Ether in a Sealed Tube, Six Hours at 100°

Wt. Silver Salt	c. c. Methyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent O–Ester
Approx. 0.5 grms.	2	0.2654 grms.	0.0510 grms.	80.8
Approx. 0.5 grms.	2	0.2741 grms.	0.0515 grms.	81.2
			Average	81.0

Silver Salt of Methyl Sulphone and Ethyl Iodide in Ether in a Flask at Room Temperature, Four Days

Wt. Silver Salt	c. c. Ethyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent O–Ester
Approx. 0.5 grms.	2	0.5144 grms.	0.0106 grms.	97.9
Approx. 0.5 grms.	2	0.4185 grms.	0.0103 grms.	97.5
.....	..	0.1583 grms.	0.0050 grms.	96.8
			Average	97.4

Silver Salt of Methyl Sulphone and Ethyl Iodide in Ether in a Sealed Tube at 100°, Six Hours

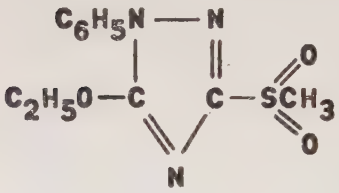
Wt. Silver Salt	c. c. Ethyl Iodide	Wt. Total Ester	Wt. N–Ester	Per Cent O–Ester
Approx. 0.5 grms.	2	0.2030 grms.	0.0078 grms.	96.2
Approx. 0.7 grms.	2	0.3084 grms.	0.0100 grms.	96.8
			Average	96.5

Since 97 per cent of the ethyl O–ester is obtained by alkylating the silver salt of the methyl sulphone, this ester is obtained in practically a pure state by recrystallizing the mixture. By using the method previously described,[25] an analysis was made of the recrystallized O–ester and it was found that there

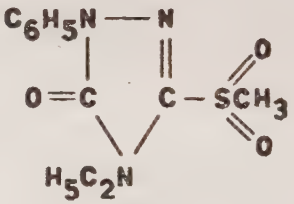
[25] See page 26.

was only about one per cent of the N–ester present. Several recrystallizations would doubtless remove this small amount.

The corresponding N–ester is obtained in a pure state from the sodium salt by hydrolyzing away the O–ester which is formed simultaneously. 1–Phenyl–5–ethoxy–4–5–dihydro–3–triazolyl methyl sulphone, XIX, is a stable, white, crstalline substance which melts at 97°. The isomeric N–ester, XX, is very similar in appearance but has a different melting point, namely, 116°.



XIX



XX

By considering the above ratios we see that a widely different ratio of esters is obtained upon alkylating the sodium and silver salts. From the sodium salt of the methyl sulphone and ethyl iodide, 90.4 per cent of nitrogen ester is obtained, while from the silver salt and ethyl iodide 97 per cent of oxygen ester is obtained. In the case of the sodium and silver salts of methyl sulphone treated with methyl iodide, from the sodium salt we obtain 96.8 per cent nitrogen ester, and from the silver salt 81 per cent oxygen ester. The ratios show *conclusively* that both esters are formed in each case and since the changes in temperature, time, and concentration had no appreciable effect, the theories of Wheeler, Comstock, Nef and Michael are not applicable to these cases. If the esters rearranged under the experimental condition it would be difficult to see how 90.4 per cent of the nitrogen ester would be obtained from the sodium salt, and 96.8 per cent of the oxygen ester from the silver salt, especially in light of the fact that these salts were heated in all cases with a large excess of the alkyl halide.

Alkylation of the Methyl Sulphone with Diazomethane

The diazomethane was prepared by the method of Von Pechman.[22] The sulphone was dissolved in alcohol and an excess of an ethereal solution of diazomethane was added, which was indicated by the yellow color of the reaction mixture. The solvents were then carefully evaporated off and the ester formed was transferred by means of chloroform to a small separatory funnel and extracted in the usual way.

Ratio of Esters from Methyl Sulphone and Diazomethane

Wt. Total Ester	Wt. N–Ester	Per Cent N–Ester
0.2332	0.1981	84.9
0.3321	0.2858	86.1
0.4499	0.3930	87.3
	Average	86.1

The ratio of esters obtained by the action of diazomethane on the methyl sulphone shows that the reactions which produce the two forms of the ester are of the same apparent order; otherwise, a constant ratio of esters for different time periods would not have been obtained. Let equation (1) represent the rate of formation of the O–ester; and equation (2) that of the N–ester. By division we get equation (3).

$$(1)\quad \frac{dx'}{dt} = K(C_{ur} - x - x')^{m}\ (C_{dm} - x - x')^{n}$$

$$(2)\quad \frac{dx}{dt} = K'(C_{ur} - x - x')^{o}\ (C_{dm} - x - x')^{p}$$

$$(3)\quad \frac{dx'}{dx} = K''(C_{ur} - x - x')^{m-o}\ (C_{dm} - x - x')^{n-p}$$

$$(4)\quad \frac{dx'}{dx} = K''' = \frac{x'}{x}$$

[22] Ber. d. Chem. Ges., **27**, 1888; **28**, 855.

If m–o and n–p were not zero, the ratio $\frac{x'}{x}$ would vary with x, and therefore with t. Since the ratio is constant, equation (4) must hold for the reaction and m–o and n–p must be zero; that is, m and o are equal, as are also n and p. In other words, the orders of the two reactions are the same with reference to both the urazole and diazomethane, as has also been found to be the case with all of the other urazoles studied up to this time.

As stated before in the theoretical discussion the only case found in this laboratory in which the alkyl esters of the urazoles rearranged when heated was the case of allyl iodide and 1–phenyl–4–methylurazole investigated by Johnson.

The following table[23] illustrates this point:

Table XIX—0.3 N Silver 1–Phenyl–4–Methylurazole and 0.3 Vol. N Allyl Iodide in 40 Per Cent Alcohol at Various Temperatures

Temperature	Time in Hours	Total Product	Per Cent N–der.
0°	1	0.2633	82.2
30°	0.25	0.2227	78.8
60°	0.5	0.2533	78.8
60°	2	0.2052	78.5
100°	0.25	0.2297	89.7
100°	1	0.2048	98.4

Table X [24]*—0.3 N Sodium Salt and 0.3 Vol. N Allyl Iodide in 40 Per Cent Alcohol at Various Temperatures*

Temperature	Time in Hours	Total Product	Per Cent N–der.
0°	2	0.0262	98.5
0°	24	0.1591	98.0
30°	0.25	0.1105	97.9
60°	0.25	0.2609	99.2
100°	0.16	0.2362	98.7
100°	0.25	0.2635	95.3

[23] Acree, Ber. d. Chem. Ges., **41**, 3230.
[24] Ber. d. Chem. Ges., **41**, 3228.

Tables X and XIX show that in the case of the sodium salt the constant ratio of esters is obtained regardless of time and temperature, while in the case of the silver salt the ratio changes appreciably with variation in time or temperature or both. These tables show that up to 60° the ratio of esters is a constant, regardless of the time of reaction. At 100° the ratio of esters from the silver salt varies with the time; in fifteen minutes 89.7 per cent N–ester was obtained, while in one hour 98.4 per cent N–ester is formed. These facts seem to indicate that the oxygen ester formed is stable below 60°, but above this is unstable and begins to rearrange into the nitrogen ester. With all other alkyl halides the salts of 1–phenyl–4–methylurazole gave a constant ratio of esters, regardless of variation in temperature or time of reaction.

Work is now being carried on in this laboratory to investigate the ratio of esters formed from allyl iodide and various salts of the methyl sulphone. These ratios of esters are being determined at 22°, 60° and at 100° in order to learn the effect of temperature, if any, on the ratio of esters formed. Known mixtures of the oxygen and nitrogen esters will be heated with allyl iodide to determine whether any rearrangement takes place.

III. The Tautomerism of the Amides.

Theoretical

The constitutional formula of amides in general is usually written in the form, $RC(:O)NH_2$. Evidence has been obtained, however, which seems to indicate that an amide may also have the constitution, $RC(:NH)OH$. Tafel and Enoch[26] found that when the silver salt of benzamide was treated with ethyl iodide, and the reaction allowed to take place at room temperature, a benzimidoethyl ester was formed instead of the expected benzethylamide. Wheeler and Johnson[27] found that when benzimidoethyl ester was heated with ethyl iodide in a sealed tube at 100°, the imidoester was rearranged into ethylbenzamid. They concluded that the amides are not tautomeric, but that the above mentioned isomeric products were formed by a rearrangement of one form.

Matsui[28] prepared both aliphatic and aromatic imidoesters by the action of dimethyl sulphate on various amides at temperatures below 100°. He believed that the formation of the imidoester took place by direct alkylation of the enolic form and not by the addition of the dimethyl sulphate to the ketonic form, with subsequent rearrangement.

Stieglitz and Ransom[29] prepared chlorimidomethyl benzoate, $C_6H_5.C(NCl).OCH_3$, by the action of diazomethane, CH_2N_2, on benzoylchloramide, $C_6H_5.CO.NHCl$.

The above evidence is not sufficient to enable one to decide whether amides in general are tautomeric or whether they exist in only one form. In the cases of alkylation reactions discussed above, the investigators did not work quantitatively as we did in studying the urazoles, hence they easily could have over-

[26] Ber. d. Chem. Ges., **23,** 103.
[27] Am. Chem. J., **21,** 185.
[28] Mem. Coll. Sci. Eng. Kyoto, **2,** 397-400; 37-45.
[29] Ber. d. Chem. Ges., **34,** 1615.

looked the presence of one compound if formed in small amount.

We have begun a study of amides and thioamides in order to determine whether they are really tautomeric compounds or whether only one compound is formed upon alkylation and this then rearranges into the isomeric alkyl derivative. Since an isomer of glycolamide has already been made by Steiner,[30] Plinke,[31] and Eschweiler,[32] we have selected this as the first amide to investigate. Glycolamide, $CH_2OHC(:O)NH_2$, melts at 120° and its isomer, glycolimidohydrin, $CH_2OHC(:NH)OH$ melts at 160°. The methods described for making the latter compound were found to be very unsatisfactory, as the yield is very poor. Work is now in progress to devise a method of obtaining this compound in larger yield.

Preparation of Compounds

Glycollic acid nitrile: This compound was prepared by mixing equivalent amounts of 90 per cent hydrocyanic acid and 35 per cent formaldehyde and allowing the reaction mixture to stand for several days. It was found that the addition of less than ½ c. c. of aqueous ammonia catalyzed the reaction to such an extent that vigorous ebullition took place. The greater part of the water was removed by distillation in vacuo at 30 to 40 m. m. pressure. The nitrile remaining in the flask was dissolved in ether and dried with anhydrous copper sulphate. The ether was then filtered off, evaporated and the nitrile fractionated in vacuo. The yield varied from 70–80 per cent.

Dry glycollic acid nitrile can be distilled at 760 m. m. pressure with only slight decomposition. It boils at 103° at 16 m. m. pressure. When heated in vacuo with a small amount of water at a temperature of 60°–80° it decomposed suddenly with evolution of heat and changed over into a black, tarry mass. When the nitrile is heated with larger quantities of water, the greater part of the water can be distilled off in

[30] Diss. Hannover, 1896.
[31] Diss. Hannover, 1898.
[32] Ber. d. Chem. Ges., **30,** 998-1003.

vacuo without the nitrile undergoing any appreciable decomposition.

Glycolimidoester hydrochloride: This substance was prepared by the method of Pinner[33] from glycollic acid nitrile. The yield of this product is practically quantitative.

Glycolimidohydrin: Steiner obtained this compound by adding the imidoester hydrochloride mixed with ether to a 33 per cent solution of potassium carbonate in water. The ethereal layer was pipetted off and the solution extracted further with ether. The ethereal extract was then heated with water. The residue remaining after evaporation of the solvents was recrystallized several times from absolute alcohol. We found that this method yielded only a few tenths of a gram of the imidohydrin from 20 grams of the imidoester hydrochloride. Plinke's method, though unsatisfactory, was found to be much better. He neutralized the imidoester hydrochloride by adding it in small portions to a suspension of freshly precipitated, alkali free, silver oxide in cold water. At the same time the free imidoester is saponified to the imidohydrin. The solution is filtered, treated with hydrogen sulphide, and again filtered. It is then evaporated to dryness and the residue recrystallized as before. By this method about 0.5 grms. of the imidohydrin was obtained from 10 grms. of the imidoester hydrochloride. The reason why the yield is poor is because the imidoester hydrychloride is rather unstable and is readily decomposed by water. The imidohydrin melts at 160°.

[33] Pinner, Die Imidoather und Ihre Derivate, 2.

BIOGRAPHY

Herbert August Lubs, the author of this dissertation, was born in Savannah, Georgia, December 20, 1891. His early education was obtained in the public schools of that city. After leaving the Savannah High School, he entered Newberry College, South Carolina. From this institution he received the degree of Bachelor of Arts in June, 1910. In the fall of that year he entered the Johns Hopkins University, with Physical Chemistry and Applied Electricity as subordinate subjects.